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DISCOVERY OF INTERNAL TELIA PRODUCED BY A SPECIES OF CRONARTIUM

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INTRODUCTION

Adams (1)[1] has recently listed the reports of a number of investigators who have found rust sori developing internally in the host tissue. Both Adams (1) and Wolf (7) fail to mention the work of Bolley and Pritchard (2) and Pritchard (5, 6), who made careful studies of internal sori in wheat grains. A review of the literature shows that pycnia, æcia, uredinia, and telia have been found inside the tissue of the host plant, producing what were apparently normal spores. Table I summarizes all the accounts of internal rust sori which are known to the writer.

TABLE I.—*Summary of accounts of internal rust sori*

Author.	Parasite.	Spore stages.	Host.	Where located.
Adams, J. F. (1)...	*Nigredo caryophyllina* (Schrank) Arthur = *Uromyces caryophilinus* (Schroeter).	II	*Dianthus caryophillus* L.	In leaves.
Atkinson, G. F., and Edgerton, C. W. and Reddick, Donald (7).	*Nigredo caladdii* (Schw.) Arthur = *Uromyces caladdii* Farlow.	I	*Peltandra virginicia* (L) Kunth.	(?)
Bolley, Henry L., and Pritchard, F. J. (2).	*Puccinia graminis tritici* E. and H.	II and III.	*Triticum* sp.....	Beneath bran layer and about embryo of seed.
Eriksson, J., and Henning, E. (5)	*Puccinia glumarum* (Schmidt) Eriks. and Henn.	II and III.	Cereal grains....	In pericarp.
Fromme, Fred D. (4).	*Puccinia claytoniata* Peck.	0	*Claytonia virginica* L.	Deep in parenchyma of stem.
Pritchard, F. J. (6).	*Puccinia graminis tritici* E. and H.	III	*Triticum* sp.....	In seed near hilum.
Pritchard, F. J. (5).	*Puccinia graminis tritici* E. and H.	III	.....do.....	In pericarp of wheat grain.
Reddick, Donald (7).	*Puccinia graminis* Pers.	I	*Berberis vulgaris* L.	In fruit.
Do.....	*Dicaeoma poculiforme* (Jacq.) Kuntze = *Puccinia graminis* Pers.	II	*Secale* sp.....	In stem.
Smith, W. G. (5)...	*Puccinia graminis* Pers.	III	*Avena* sp.....	Next to gluten layer of seed.
Wolf, F. A. (7).....	*Puccinia angustata* Peck.	I	*Lycopus virginicus* L.	In pith and parenchyma tissue of petioles and stems.

[1] Reference is made by number to "Literature cited," p. 332.

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A glance at the table shows that practically any part of the host plant may contain internal sori. According to the accounts of different authors, sori were found buried deep in the tissue of the host plants, freeing their spores into hollow stems, or intercellular spaces, and in some cases making room for the lengthening spore chains by forcing aside the surrounding parenchyma cells (Pl. 88, *B*). Of course, the sori in seeds had little room to expand. Fromme (3, 4) has reported odd cases where the pycnium was located in the æcium. The discovery of these internal sori has probably been accidental in all cases, although the investigators may have been looking for abnormal conditions.

OBSERVATIONS ON THE INTERNAL TELIA OF CRONARTIUM RIBICOLA

It will be noted that the fungus genera mentioned in Table I all belong to the Puccinia and Uromyces groups. So far as the writer is aware, there have been no reports of internal sori of any species of the genus Cronartium. In the course of intensive investigations on *Cronartium ribicola* Fisher, the white-pine blister rust, a striking case of the development of internal telia was discovered in the petiole of *Ribes roezli* (Regel) Coville and Britton. The plant was inoculated in July, 1915, and was kept in the greenhouse through the following winter. On February 28, 1916, telia were found by Spaulding [1] on the petiole of one dead leaf and of one partially dead leaf, both still remaining on the plant. These petioles were killed, embedded in paraffin, and sectioned. Close to the base of the leaf the pith and pericycle regions (Pl. 88, *A*) of the petiole were found to be practically stuffed with the mycelium of the parasite, while farther from the leaf base there was less complete destruction of the host tissue. Haustoria, which were larger and more numerous than those in the leaf, suggested that the mycelium was more active in the petiole than in the leaf. At intervals in the tissue of the regions mentioned telia had begun to develop (Pl. 88, *E*). The direction of growth of what would normally be telial columns was very variable, some growing toward the outside, some toward the center of the petiole. Quite naturally the telia could not produce a typical telial column in such cramped quarters, and the variations were such as one would expect; the sori were broadened out (Pl. 88, *D*), the spores compressed, and the columns where partially developed were coiled or bent by the pressure on the free ends (Pl. 88, *C*). Despite the distortion of the columns, the spores quite closely resembled the spores from a normal sorus, lacking, however, in many cases, the heavier brown wall, characteristic of the fully developed spores of an external column. Possibly the walls would have taken on the brown color as the spores matured. In several of the sori, older than the others, the spores were just begin-

[1] Dr. Perley Spaulding, of the Office of Forest Pathology, supplied the material for this study, and kindly furnished the data on the inoculation.

ning to develop the wall thickening and color change. The walls of the spores at the tip of the telial column shown in Plate 88, *C*, were identical in color and thickness with the walls of spores in external columns. The measurements of the internal spores, 10 to 20 by 20 to 40 μ, agreed well with those of normal spores, considering the conditions under which the internal spores were produced. There was at first some doubt as to the true nature of the spores, for some of the sori were surmounted with a peridium like the peridium of a normal uredinium. This would not exclude the possibility that the sorus was a telium, for the normal telial column often arises from an old uredinium. In this case, indeed, there could be no question whether the spores were urediniospores or teliospores, since the mycelium, which, as mentioned above, sometimes stuffed the pith region, was typically binucleate; the spores were uninucleate; and the change from the binucleate condition to the uninucleate condition occurred just after the spores were cut off from the basal cells of the sorus. This cytological evidence, agreeing as it does with cytological conditions in sori producing teliospores, completely established the identity of the internal sori as telia, even when the spores were very young.

The occurrence of the petiole infection is rather common in both wild and cultivated species of Ribes where the general infection is heavy. In two other species examined, *R. nigrum* L. and *R. cynosbati* L., no internal telia had been formed, although the mycelium was abundant and normal telia present on the surface of the petioles. The epidermal region of the petioles of *Ribes* spp. undoubtedly offers more resistance to the developing telia than the epidermis and palisade cells of the leaf. The sori probably are unable to break through the stiffer layer in the petiole; hence, their development as far as possible within the inclosing tissue. Unquestionably internal sori should be regarded as rather common teratological phenomena, developed in spite of their unfavorable position. Morphologically they have no special significance. Their development is to be expected whenever the point at which the sorus begins to form is located beneath a layer of tissue which offers a greater resistance than the developing sorus can overcome. Accidental discovery of the sori after the material had been killed and embedded has precluded any spore germination experiments. Investigators, however, have found the internal mycelium, and the teliospores themselves, to be in a living state after a considerable time, even in comparatively dry tissue. Pritchard (5) figures the teliospores as undergoing a sort of palmella-like division which may be the equivalent of germination. In his material the mycelium was certainly alive for a long time. There is a possibility that the phenomena described by Pritchard (5) might be observed under suitable conditions in the internal teliospores of *Cronartium ribicola*.

SUMMARY

(1) All four types of rust sori have been found developing internally in the host-plant tissue, producing spores which appear quite normal and which fill intercellular spaces or force aside the softer tissue.

(2) The fact that *Cronartium ribicola* Fisher produces internal telia is here reported for the first time. These telia form spores inside the petioles of species of Ribes, chiefly in the pith and pericycle region.

(3) Internal sori should be regarded as rather common teratological phenomena.

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PLATE 88

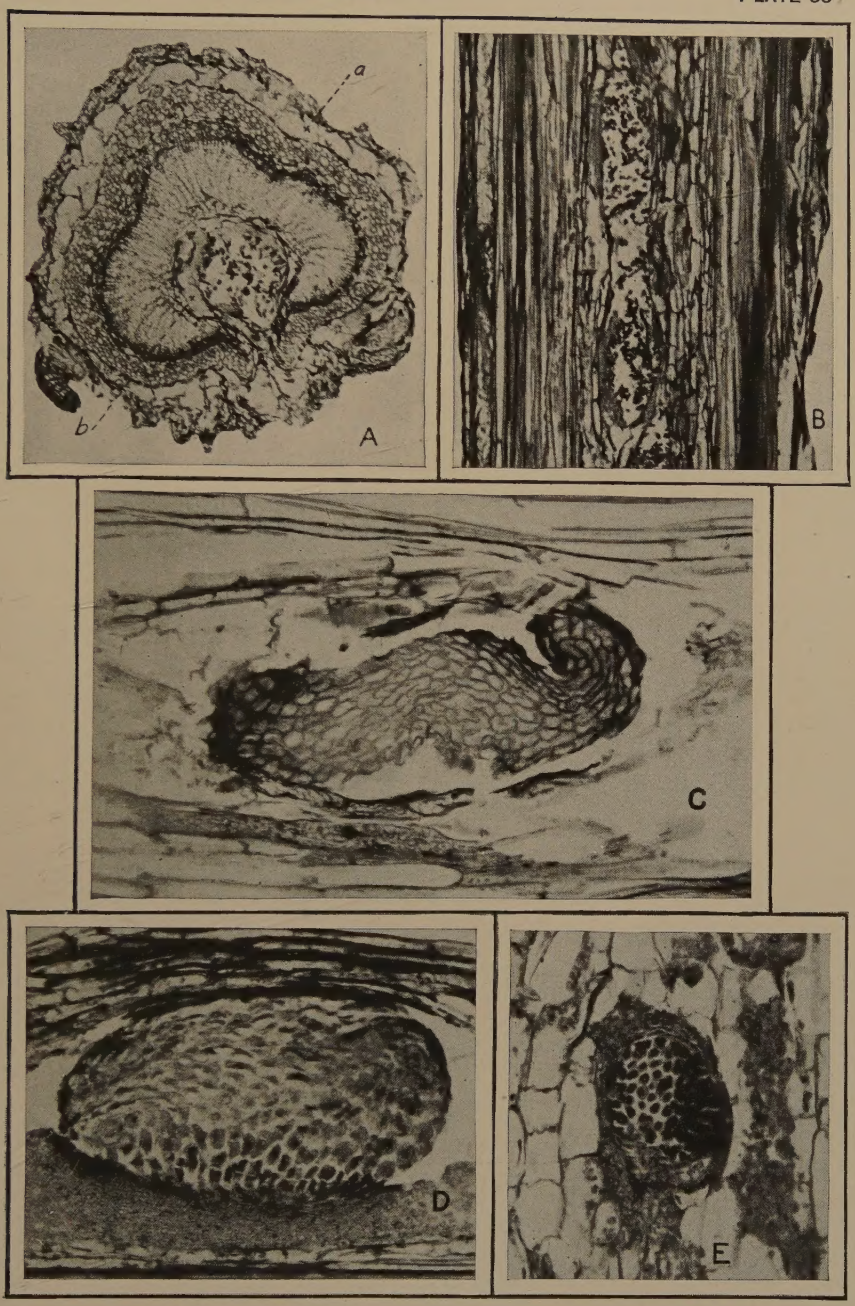
A.—Cross section of a petiole of *Ribes roezli*, showing the pericycle (*a*) and pith (*b*) regions which are stuffed with the mycelium of *Cronartium ribicola*. Most of the pith cells have been destroyed. Teliospores partially fill the cavity.

B.—Longitudinal section of the same petiole, showing the manner in which the sori force aside the parenchyma cells of the pith.

C.—Internal telium of *Cronartium ribicola* from the pericycle region of a petiole of *Ribes roezli*. The telium has been forced to coil on account of the pressure of the surrounding cells.

D.—Internal telium of *Cronartium ribicola* from the pericycle region of a petiole of *Ribes roezli* flattened by pressure.

E.—Young internal telium of *Cronartium ribicola* from the center of the pith region of a petiole of *Ribes roezli*, illustrating the depth at which sori may start to develop.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